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(54) Title: PROGNOSTIC SYSTEM FOR DETERMINING INFRARED SIGNATURE PATTERNS EMITTED FROM ELECTRONIC DEVICES

(57) Abstract

An electronic prognostic and diagnostic system for determining infrared signature patterns emitted from electronic devices on circuit boards comprising a means for surveying and collecting infrared emission signature patterns emitted from each circuit assembly; at least one sensor array in communication with the means for surveying and collecting infrared emission signatures, each sensor array sensing and receiving infrared data information from the means for surveying and collecting infrared emission signatures, each sensor array generating current and voltage signals which are proportional to the infrared emission signatures thereby defining an infrared emission signature pattern; and electronic means for comparing and processing infrared data information, the electronic means for comparing and processing in electrical communication with each sensor array to receive the current and voltage signals, the electronic means for comparing and processing further including a means for resolving the location of the infrared signature pattern.

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PROGNOSTIC SYSTEM FOR DETERMINING INFRARED SIGNATURE PATTERNS EMITTED FROM ELECTRONIC DEVICES

FIELD OF THE INVENTION

This invention relates to the field of electronic prognostic systems for detecting infrared (IR) emissions from electronic circuit board components, including semiconductors, capacitive elements, resistive elements and inductive devices. The system is capable of identifying problematic electronic circuits and also capable of predicting the probable failure of components on the circuit board over time. The present invention is highly useful in those applications, such as flight critical systems and weaponry, where redundant electronic circuit assemblies are employed.

BACKGROUND OF THE INVENTION

A vast amount of electronic circuit boards are available today for a wide variety of functions. For example, circuit boards with electronic circuitry exist for such fields as handheld calculators, communications systems, servo loops, automatic control devices, personal computers, video applications and generally for the field of entertainment. As technology changes, the complexity of these circuit board designs also change, which in turn leads to changes in the reliability of the circuit board. As circuit board designs become more complex, circuit designers must be acutely aware of the potential failure of the electronics boards so as not to cause a system critical failure.

While many circuit designs today utilize redundant circuitry to ensure the normal operation of a circuit even after a failure occurs, it is still difficult to determine whether the assembly is functional or has the possibility of early failure. Additionally, in some applications, it is difficult to detect whether the circuit board has been subject to electrostatic discharge. In some circuit boards, electronic logic is embedded into the circuit design to determine if a failure exists, but this logic only determines when the circuit fails after it fails. Further, these electronic logic designs draw valuable voltage and current which may take power away from other, more important circuitry. In still other circuitry, multiple electronic circuits are built in to the main circuit (such as, for example, as a redundant circuit in a nuclear warhead) to ensure the safe operation of the circuit even when certain components might fail.

The proliferation of electronics has resulted in an increased knowledge base of in-circuit testing to determine whether a failure of critical nature has occurred. These diagnostic circuit methodologies are limited because of the proportional relationship of

the built-in test circuit cost to the number of circuit functions tested. Further, increased built-in test circuitry decreases overall system reliability. And, while such built-in test circuitry is capable of detecting failures, such circuitry does not generally support prognostics of the overall circuit. With the increase in the use of electronics and the increased need for performance of the electronics, a means for determining the circuit boards functional characteristics (e.g., the board=s general health) is needed which will not impose a penalty on the basic reliability of the system.

It is known that when a powered electronic circuit is in operation, certain IR signature patterns are emitted which can be detected. When the electronic circuit=s operating characteristics are modified or changed (such as, for example, due to a certain circuit malfunction), certain IR emission patterns will result due to the malfunction. Thus, when a component fails due to an open circuit, the IR signature of the overall circuit assembly is observed to decrease. If a circuit becomes fuzed, the IR signature pattern is observed first to increase, then decrease. Additionally, certain IR signature patterns may result when wire bonding problems exist. Of course, the exact IR signature pattern will vary depending on the type of malfunction, type of expected malfunction and also on the electronic circuit being surveyed (e.g., the IR signature pattern on an open circuit for each specific integrated circuit and each component will exhibit unique characteristics. Further, the operating characteristics of the circuit board (such as operating frequency, the environmental characteristics and the exact application performed by the circuit board) may change the IR signature patterns which are emitted.

As such, it is desirable to locate and detect early in the manufacturing process any existing or latent (undiscovered) defects to aid in the objective of quality control. It is equally desirable to have a real-time system for locating and detecting existing and latent defects as the electronic circuitry is in operation in the field. In this fashion, the defective circuits can be replaced quickly without affecting the overall end use application. Further, information resulting from defects occurring in the field which are detected may assist designers in the manufacturing of electronic circuits.

Prior to the present invention, the prior art disclosed several inventions capable of indicating manufacturing defects in products by detecting changes in thermal radiation. Some of these inventions are found in U.S. Patent No. 5,032,727 to Cox, Jr. et al., 5,760,400 to Prekel et al. U.S. Patent Nos. 5,208,528 to Quintard and 5,052,816 to Nakamura et al. require that the circuitry be excited in some form (e.g., thermally or by laser beam) before surveying the electronic device.

U.S. Patent No. 5,302,830 to Shivanandan disclosed a method for measuring thermal differences in IR emissions which were emitted from a single microdevice which are specific IR emissions uniquely associated with the correct functioning of the microdevice. Shivanandan discloses use of an image sensor capable of measuring infrared radiation at wavelengths in a single micro device of less than 5 micrometers. The image sensor includes a large optical lens system, an optical window, a two dimensional array detector for detecting electromagnetic radiation, a plurality of bandpass filters to filter out signals greater than 5 micrometers, a cold shield and an electronic signal processor. Shivanandan teaches that the array detector must be positioned next to a cold surface in order to operate at temperatures less than seventy-seven degrees Kelvin. This invention is not likely a candidate for remote field operation, such as may be required for a tank in battle or airplane electronics.

In contrast to the prior art disclosures, the present invention utilizes a device capable of surveying and collecting IR signature patterns in field operating environments (-55 to 85 C) to maintain surveillance on one or more electronic circuit assemblies containing one or more electronic circuits, image processing capabilities to gather data relating to the emitted IR signatures and processing means for the processing and comparison of the IR signature patterns with known empirical IR signature data. The present invention is intended to survey electronic circuit boards adjacently, however, those skilled in the art will realize that without undue experimentation, the present invention can be directly incorporated into the electronic circuit board design as needed.

SUMMARY OF THE INVENTION

The present invention includes a means for surveying and collecting infrared emission signature patterns emitted from one or more circuit board assemblies; at least one sensor array in communication with the means for surveying and collecting infrared emission signatures, each sensor array sensing and receiving infrared data information from the means for surveying and collecting infrared emission signatures, each sensor array generating current and voltage signals which are proportional to the infrared emission signatures thereby defining an infrared emission signature pattern; and electronic means for comparing and processing infrared data information, the electronic means for comparing and processing in electrical communication with each sensor array to receive the current and voltage signals, the electronic means for comparing and

processing further data including a means for resolving the location of the infrared signature pattern.

Further, the electronic means for comparing and processing 19 includes electronic means for sensing the electrical current and voltage 31 which powers the circuit board assembly being monitored and also, electronic means for comparing the supplied current and voltage to empirical data to aid in the determination of prognostic and diagnostic health of the circuit assembly being monitored. Additionally, the electronic means for comparing and processing includes electronic means to compare information processed from the IR emissions signature, the supply current and the supply voltage to determine the failure and future failure of the circuitry being monitored.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates the an embodiment of the present invention surveying an single electronic circuit board assembly.

Figure 2 illustrates a type of lensing system which may be utilized with the present invention.

Figure 3 illustrates a block diagram of the present invention;

Figure 4 illustrates another embodiment of the present invention surveying a plurality of electronic circuit board assemblies as might be found either in a test rack chassis or on-board a field application.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention is a prognostic system for determining infrared signature patterns emitted from electronic devices 10 as illustrated in Figure 1. The present invention 10 is a prognostic system for electronic devices on one or more circuit board assemblies 11_n, the system comprising a means for surveying and collecting infrared emission signature patterns 13 which may be emitted from each component 15_n on each circuit board assembly 11_n, at least one sensor array 17_n which is in communication with the means for surveying and collecting infrared emission signatures, and means for comparing and processing infrared data information 19.

In one embodiment of the present invention, the means for surveying and collecting infrared emission signature patterns 13 is an optical lens. This type of lens might be useful in those applications which require collection of IR emission signatures

or other electromagnetic frequencies from a broad area. Optical lens 13 is preferably a broad field lens for collection of the IR energy from a broad area where the primary purpose is to capture the energy emissions rather than pure image collection. Additionally, it is also contemplated that a fresnel lens (such as seen in Figure 2) would suffice as the IR collection mechanism for the present invention.

The preferred means for surveying and collecting infrared emission signature patterns 13, however, is a holographic device, and in particular, a holographic lens. While many holographic lenses may exist or come to exist, it is believed that a commercially available holographic film lens is an optimum holographic lens. In this embodiment, holographic film lens 13 is preferred because of its flexibility and because it can readily survey and capture infrared emission signature patterns emitted from one or more circuit assemblies 11_n. A holographic film lens allows more efficient collection of IR energy emissions which correlates to the IR energy source. Indeed, in the preferred embodiment, because the system is to monitor circuit board assemblies broadly, the holographic film lens, and thus the overall system 10, is optimally located adjacent to each circuit assembly 11_n so as not to disturb the placement of each circuit assembly 11_n. In this fashion, the present invention 10 with a holographic film lens 13 can be retroactively fitted into those designs which already exist on the market today. However, those of skill in the art will come to realize that the present invention 10 can be directly incorporated into the design of each circuit board assembly 11_n as desired.

As seen in Figure 1, at least one sensor array 17_n, such as, for example, a subminiature IR camera, is in communication, preferably electrical communication, with the means for surveying and collecting infrared emission signatures 13. In the preferred embodiment, each sensor array 17_n is a subminiature limited array. A subminiature limited array or IR camera is believed optimal for the present invention because the intent of the invention is to be nonobtrusive and a subminiature sensor assembly facilitates applying the present invention as a new device or a retrofittable device for existing applications.

In operation, each sensor array 17_n senses and receives infrared data information from the means for surveying and collecting infrared emission signature patterns 13. Each sensor array 17_n then generates current and voltage data information which is proportional to the infrared emission signatures to thereby define an IR emission signature pattern.

The electronic means for comparing and processing infrared data information 19

is in communication, preferably in electrical communication, with each sensor array 17_n. Means for comparing and processing infrared data information 19 is preferably software in nature, which can be executed, for example, on a microprocessor, ASIC or a computer which can generate a visual display to the operator. The electronic means for comparing and processing 19 also receives the data relating to the current and voltages supplied to power the electronics assembly being monitored.

As seen in the block diagram of Figure 3, the means for comparing and processing 19 can also include electronic means for comparing the supplied current and voltage to the data from the IR sensor array 29 (or subminiature IR camera) and, based on previously stored empirical data, using this comparison in the determination of the prognostics or diagnostics of the circuit board being monitored. Because IR signature patterns emitted from a circuit board assembly 11_n will vary depending on numerous conditions, means for comparing and processing infrared data information 19 must have some form of storage memory or storage means 27 for storing empirical IR signature pattern data which has been previously collected. Further, due to the complexity of IR patterns, it is preferred that the means for comparing and processing infrared data information 19 be high speed to account for numerous pattern comparisons. It is envisioned that the means for comparing and processing infrared data information 19 further include a means for determining a future status 21 of each circuit board assembly 11_n, and may also further include a means for determining reliability of each electronic device 23. As such, both means for determining a future status 21 of each circuit board assembly 11_n, and means for determining reliability of each electronic device 23 define a means for correlating the infrared emission signature pattern with the empirical infrared data information as seen in Figure 3. Both the means for determining a future status 21 and the means for determining reliability of each electronic device 23 are achieved by the comparison or correlation of the stored empirical IR signature pattern data with the IR signature pattern data collected from each circuit board assembly 11_n. In this manner, the current and future health of a circuit board assembly can be predicted based on empirical data.

Optionally, the means for comparing and processing infrared data information 19 can also further include relational logic to form a neural network in either software or hardware. As known to those of skill in the art, a neural network implements a relational and anticipatory logic in an efficient manner. A neural network may be preferred in those applications which require concise correlation based on empirical

knowledge and stochastic processes.

Further, as seen in Figure 3, the means for comparing and processing infrared data information 19 may also optionally include a means for resolving the location of an infrared emission signature pattern 25. The means for resolving the location of an infrared emission signature pattern 25 may be necessary when a holographic film lens 13 is employed, because IR emissions from multiple circuit assemblies 11_n may be generated and surveyed by the holographic film lens 13. As such, it is necessary to correlate which emissions were generated from which circuit board assembly. Preferably, the means for resolving the location of an infrared emission signature pattern 25 is software oriented.

Another embodiment of the present invention is depicted in Figure 4. In this embodiment, the present invention 10' includes means for surveying and collecting infrared emission signature patterns 13' which may be emitted from each component 15_n= on each circuit board assembly 11_n= within a conventional electronics chassis cage, a sensor array 17_n= which is in communication with the means for surveying and collecting infrared emission signatures, and means for comparing and processing infrared data information 19' (not shown). In this embodiment, because of the flexibility of the holographic lens 13 employed, the present invention 10' can be retrofitted into existing electronic chassis designs, while simultaneously monitoring a plurality of circuit board assemblies 17_n= as they are in operation. Further, the electronic means for comparing and processing 19' includes electronic means for sensing the electrical current and voltage 31' (as illustrated in Figure 4) which powers the circuit board assembly being monitored 17_n= and also, electronic means for comparing the supplied current and voltage to empirical data 31' to aid in the determination of prognostic and diagnostic health of the circuit assembly being monitored.

Whereas the drawings and accompanying description have shown and described the preferred embodiment of the present invention, it should be apparent to those skilled in the art that various changes may be made in the form of the invention without affecting the scope thereof.

CLAIMS

1. A prognostic system for monitoring electronic devices on one or more circuit board assemblies being powered by current and voltage, the system comprising:
   a. means for surveying and collecting infrared emission signature patterns emitted from each circuit board assembly;
   b. at least one sensor array in communication with the means for surveying and collecting infrared emission signatures, each sensor array sensing and receiving infrared data information from the means for surveying and collecting infrared emission signatures, each sensor array generating current and voltage signals which are proportional to the infrared emission signatures thereby defining an infrared emission signature pattern; and
   c. electronic means for comparing and processing infrared data information, the electronic means for comparing and processing in electrical communication with each sensor array to receive the current and voltage signals, the electronic means for comparing and processing further including a means for resolving the location of the infrared emission signature, storage memory for storing empirical infrared data information, a means for correlating the infrared emission signature pattern with the empirical infrared data information and a means for generating a visual display.

2. The prognostic system of claim 1 wherein the means for surveying and collecting infrared emission patterns is an optical lens.

3. The prognostic system of claim 2 wherein the optical lens is a broad field lens.

4. The prognostic system of claim 2 wherein the means for collecting infrared emission is a fresnel lens.

5. The prognostic system of claim 1 wherein the means for collecting infrared emission is a holographic device.

6. The prognostic system of claim 5 wherein the holographic device is a

holographic lens.

7. The prognostic system of claim 6 wherein the holographic lens is a holographic film lens.

8. The prognostic system of claim 7 wherein the system is adjacent to each circuit board assembly.

9. The prognostic system of claim 7 wherein the system is in direct communication with each circuit board assembly.

10. The prognostic system of claim 7 wherein the sensor array is a subminiature limited array.

11. The prognostic system of claim 10 further including electronic means for comparing the supplied current and voltage to each circuit board assembly to the infrared emission signature pattern.

12. The prognostic system of claim 11 wherein the electronic means for comparing and processing infrared data information further includes relational logic to form a neural network.

13. The prognostic system of claim 12 wherein the relational logic further comprises means for determining reliability of each electronic device on each circuit board.

14. A prognostic and diagnostic system for one or more circuit board assemblies, the system comprising:

a. a holographic lens, the lens collecting infrared emission signature patterns emitted from each circuit assembly;

b. at least one sensor array in electrical communication with the holographic lens, each sensor array generating current and voltage signals which are proportional to the infrared emission signatures thereby defining an infrared emission signature pattern; and

c. processing means for calculating and comparing the infrared emission

signature patterns, the processing means for calculating in electrical communication with each sensor array to receive the infrared emission signature pattern.

15. The prognostic system of claim 14 wherein the holographic lens is a holographic film lens.

16. The prognostic system of claim 15 wherein the processing means for calculating and comparing further including a means for resolving the location of the infrared emission signature pattern, storage memory for storing empirical infrared data information and a means for correlating the infrared emission signature pattern with the empirical infrared data information.

17. The prognostic system of claim 16 wherein the holographic film lens is in close proximity to each circuit board assembly.

18. A prognostic and diagnostic system for one or more circuit board assemblies powered by current and voltage, the system comprising a holographic film lens for surveying and collecting infrared emission signature patterns emitted from each circuit board assembly, more than one sensor array in communication with the holographic film lens, each sensor array generating voltage and current data corresponding to the infrared emission signature patterns emitted, and software means for calculating, comparing, resolving and correlating the infrared emission signature patterns, the software means further including storage memory for storing empirical infrared data information.

19. The prognostic system of claim 19 wherein the means for calculating, comparing, resolving and correlating the infrared emission signature patterns further comprises a means for comparing the supplied current and voltage to the infrared emission signature patterns, means for determining reliability of each electronic device on each circuit board, a means for determining a future status of each circuit board assembly, a means for generating a visual display and relational logic to form a neural network.

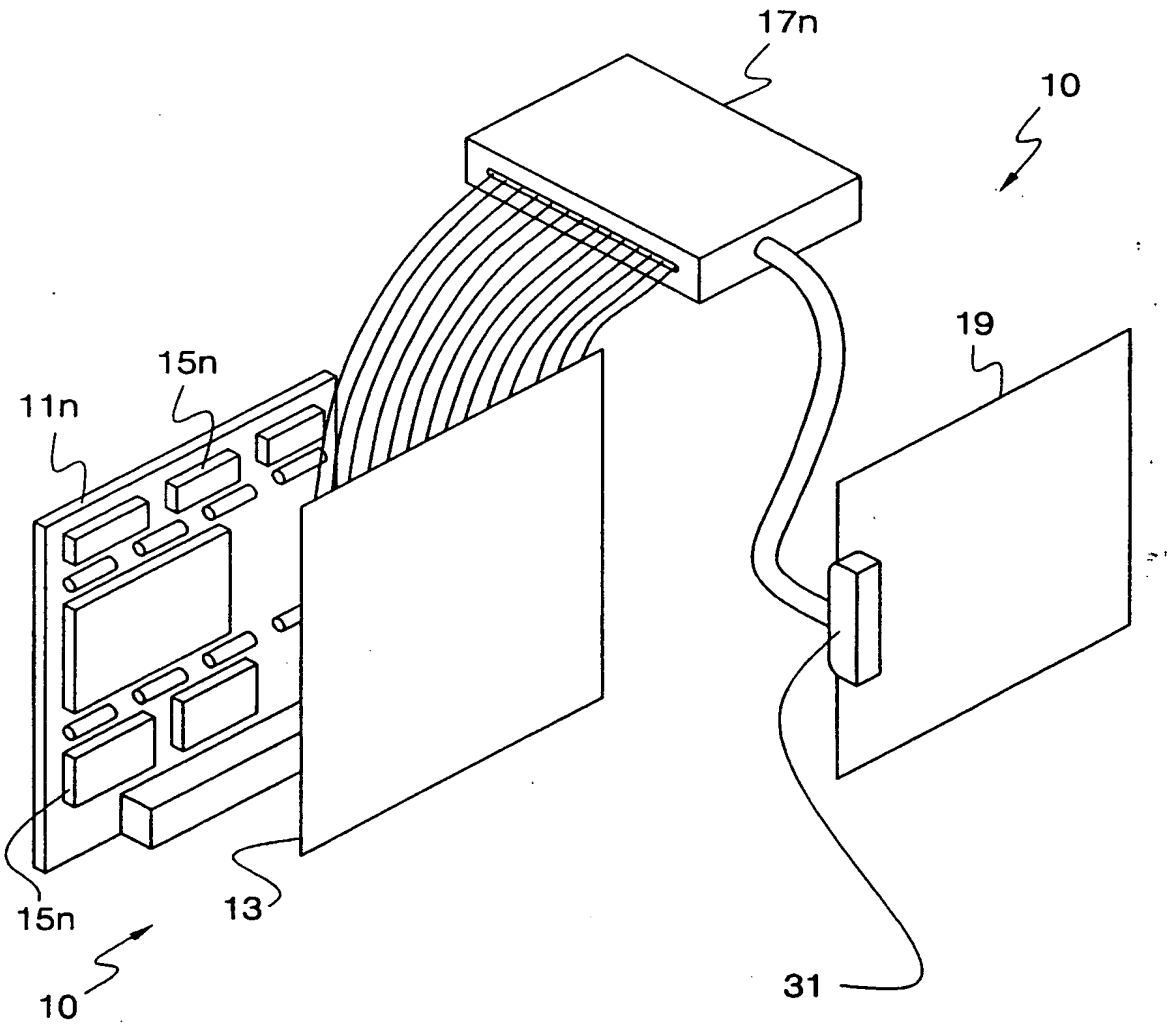

Fig. 1

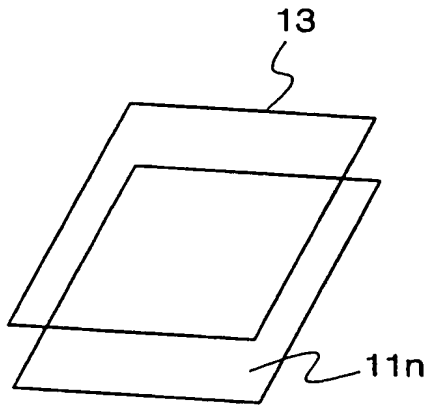

Fig. 2

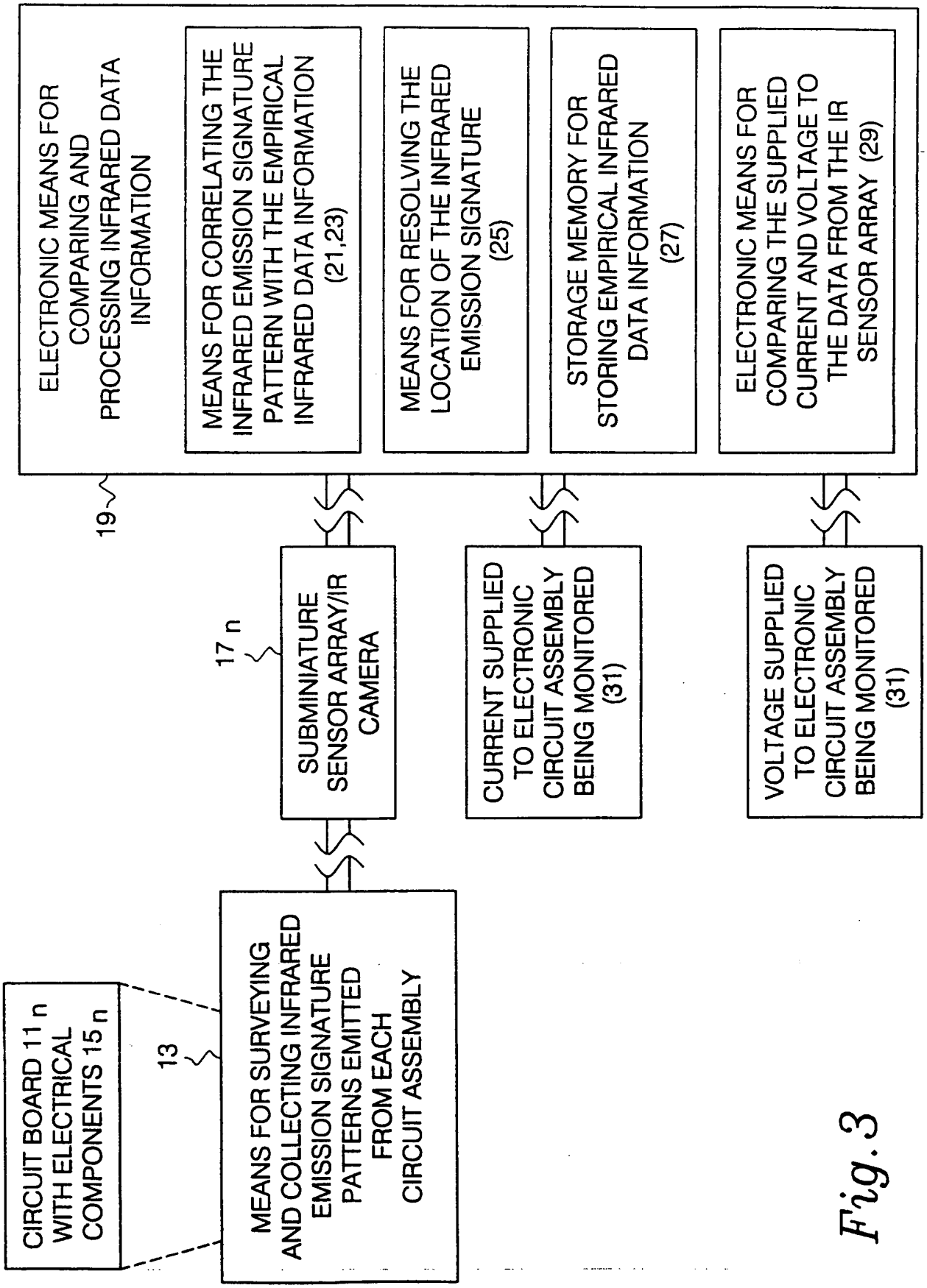

Fig. 3

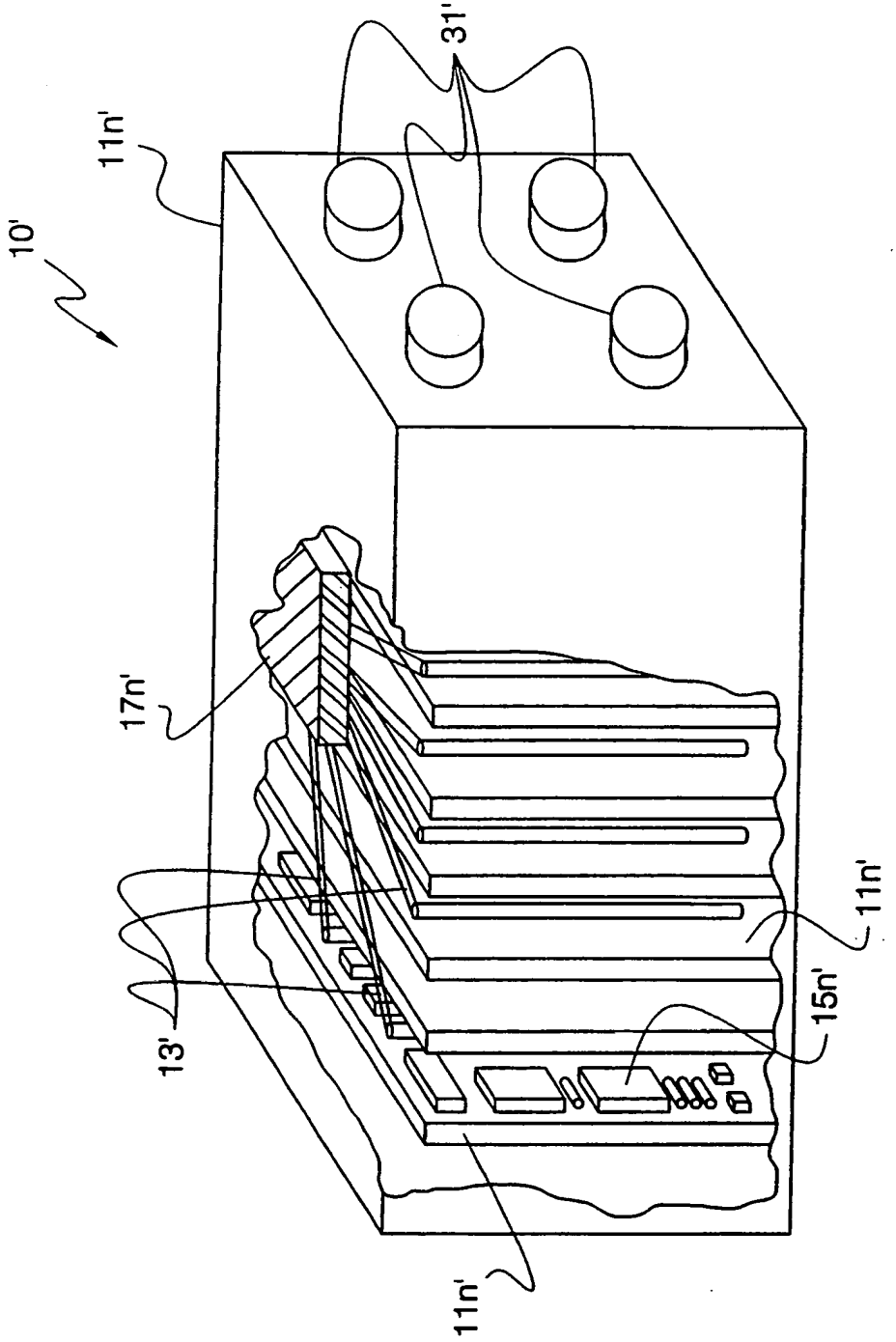

Fig. 4

INTERNATIONAL SEARCH REPORT

Int ional Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01R31/309 G01N25/72

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01R G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 1997, no. 10, 31 October 1997 (1997-10-31) & JP 09 159590 A (JEOL LTD;NIPPON DENSHI KURIEITEIBU KK), 20 June 1997 (1997-06-20) abstract	1
A	US 5 440 566 A (SPENCE HUGH F ET AL) 8 August 1995 (1995-08-08) claim 1	1,12,14, 18

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
17 May 2000	24/05/2000

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Information on patent family members

International Application No
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Patent document cited in search report	Publication dat	Patent family member(s)	Publication date
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US 5440566 A	08-08-1995	NONE	